temperature increases with decreasing pressure, or in other words when an inversion of virtual temperature prevails in a stratum, the *PH* curve for the stratum should again be curved. Reference to the adiabatic chart portrayed in figure 1 will show that the adiabats are concave *upwards*, and that tangents to the adiabats tend to approach verticality at lower temperatures, and horizontality at higher temperatures. Therefore it follows that the appropriate *PH* curve for a stratum that has an inversion of virtual temperature should rigorously be concave *downwards*, i. e., opposite in curvature to the *PH* curve for a stratum with a dry adiabatic vertical virtual-temperature gradient.

By virtue of the facts presented in the preceding two paragraphs, it is obvious that a linear *PH* curve rigorously has a sort of median position between the appropriate *PH* curves for dry adiabatic and inverted vertical virtual-temperature gradients. This may be best seen from figure 5, which shows the three types of *PH* curves in question, *with greatly exaggerated curvature* to illustrate their respective differences; the *mean virtual temperature for the stratum* is different for each different vertical virtual-temperature gradient. Since the virtual temperature at the bottom of the given stratum shown in figure 5 is fixed, the slope of the *PH* curve at the corresponding pressure level is the same no matter what the vertical virtual-temperature gradient is in the stratum immediately above. Therefore the three *PH* curves in question all start with the same slope, viz, that corresponding to the slope of the adiabats at the virtual temperature of the bottom of the stratum. This must be the slope of the linear *PH* curve which would obtain for isothermal conditions of virtual temperature. Then as a consequence of the upward concave character of the curve appropriate for dry adiabatic conditions, and of the downward concave character of the curve appropriate for inverted conditions of virtual temperature, the two curves in question must deviate from the straight line, the former to the right and the latter to the left. The differences between the horizontal projections of the respective *PH* curves shown in figure 5 are largely accounted for by the different mean virtual temperatures for the stratum that correspond to the different virtual temperature-pressure curves shown in the lower part of the figure. If the mean virtual temperature were identical for each given virtual temperature-pressure curve, then the horizontal projections would be the same in each case.

The discussion in the last paragraph suggests that a very nearly rigorous *PH* curve may be constructed by employing templates of various curvatures depending upon the mean virtual temperatures and upon the vertical virtual-temperature gradients of the particular strata. For example, one can prepare sets of templates for say three different mean virtual temperatures. Each set may consist of templates for the following vertical virtual-temperature gradients: (1) Dry adiabatic, (2) half-way between dry adiabatic and isothermal, (3) isothermal (use straight edge), (4) moderate inversion, and (5) strong inversion. Possibly (4) and (5) may be replaced by one suitable intermediate template. The templates may be made of some transparent material, such as celluloid, similar in form to that of a triangle with one side having a curvature appropriate to a given mean virtual temperature and a given vertical virtual-temperature gradient. This triangle may conveniently be slid to and fro with one straight edge parallel to the isobars, while the curved edge retains the proper direction relative thereto. The range of vertical virtual-temperature gradients to which the given template pertains may be graphically indicated by two fine dark lines of proper slope inscribed on the transparent material. These refinements are of course not justified in many cases; under such circumstances the methods previously outlined for the construction of the *PH* curve may be employed.

REFERENCES TO LITERATURE

(1) V. Bjerknes and Collaborators. Dynamic Meteorology and Hydrography. Part I, Statics, pp. 61–88. Washington, 1910.

(2) G. Stüve. Aerologische Untersuchungen zum Zwecke der Wetterdiagnose. Arbeiten des Preussischen Aeronautischen Observatoriums bei Lindenberg, Band XIV, 1922, Wiss. Abh., pp. 104–116.

(3) H. Hertz. Graphische Methode zur Bestimmung der adiabatischen Zustandsänderungen feuchter Luft. Meteorologische Zeitschrift, I. Jahrgang, 1884, Berlin, pp. 421–431.

(4) O. Neuhoff. Adiabatische Zustandsänderungen feuchter Luft und deren rechnerische und graphische Bestimmung. Abhandlungen des Königlich Preussischen Meteorologischen Instituts, Bd. I, No. 6, Berlin, 1900, pp. 271–305. (Translation of this may be found in Cleveland Abbe's "Mechanics of the Earth's Atmosphere", third collection, Washington, D. C., 1910).

(5) H. Hergesell und E. Kleinschmidt. Über die Kompensation von Aneroidbarometern gegen Temperatureinwirkungen; and Nachtrag zu der Arbeit "Über die Kompensation von Aneroidbarometern gegen Temperatureinwirkungen". Beiträge zur Physik der freien Atmosphäre, Band 1, 1904–05, pp. 108–119 and 203–210.

(6) R. T. Birge. Probable Values of the General Physical Constants. Physical Review Supplement (now Reviews of Modern Physics) vol. 1, No. 1, July 1929, pp. 1–73 (see particularly pages 28–29 and 30–33).

(7) L. Holborn, K. Scheel, F. Henning. Wärmetabellen der Physikalischen Technischen Reichsanstalt. 72 pp., Braunschweig, 1919 (see particularly pages 56–58).

(8) H. W. Moody. A Determination of the Ratio of the Specific Heats and the Specific Heat at Constant Pressure of Air and Carbon Dioxide. Physical Review, vol. 34, 1st series, 1912, pp. 275–295 (see pp. 290–294).

(9) W. Bowie. Investigations of Gravity and Isostasy. U. S. Coast and Geodetic Survey, Special Publication No. 40, Washington, D. C., 1917, 196 pp. (see p. 134).

(10) F. R. Helmert. Über die Reduction der auf der physischen Erdoberfläche beobachteten Schwerebeschleunigungen auf ein gemeinsames Niveau. Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften, Berlin, 1902, pp. 843–855 and 1903, pp. 650–667 (see particularly 1903, p. 651).

FLOODS IN THE SACRAMENTO VALLEY DURING APRIL 1935

By E. H. FLETCHER

[Weather Bureau, Sacramento, Calif., May 1935]

On April 6–7 a low-pressure area of marked intensity and wide extent, whose center moved inland from the ocean along the California-Oregon boundary, caused heavy rains generally throughout northern California, culminating in torrential downpours in several localities of the Sacramento basin. This was the primary cause of the flood in question. However, there were two other contributing factors of importance.

First, there was an unusually heavy snow cover in the mountain area at moderate elevations; and the rapid run-off that occurred over the American, Feather-Yuba, and upper Sacramento drainage areas was augmented by melting snow from rains that extended well up into the mountain snow fields. The material source of snow water was in a belt from about 4,000 to 5,000 feet, where the snow was less compact. The winter and early spring had brought unusually heavy snowfall to the mountain area that is drained by the streams tributary to the Sacramento and lower San Joaquin Rivers. The seasonal snowfall at Norden, elevation 6,871 feet, near the Sierra summit, to the end of March 1935, was 546 inches, which is the greatest fall for a corresponding period since 1907, and the accumulated depth on the ground April 6 was 144 inches, with the snow line extending down to the 4,000-foot level or lower in places.

Second, at the beginning of the storm referred to above, river stages were already rather high in the valley streams.

On Sunday morning, April 7, following the precipitation of a preceding storm, there was a crest at Colusa of 21.9 feet, and the stages at Knights Landing and Sacramento were also fairly high, 28 and 21.6 feet, respectively. At this time the new storm was setting in throughout northern California, and during the next 24 hours rainfall was general, but not exceedingly heavy except over the drainage areas of the American and Bear Rivers and the creeks east and west of Red Bluff. In these areas local rains of cloudburst proportions were experienced late Sunday. At Sacramento, unprecedented excessive precipitation occurred, the total for a 24-hour period being 3.35 inches, of which 1.65 inches fell within 1 hour and 2.62 inches in 2 hours. This established a new maximum rainfall intensity record for Sacramento for periods up to 2 hours. Sewers were inadequate to carry the volume of water, resulting in the flooding of streets and basements in the low sections of the city. Water backed up into the first floor of the State Capitol and other buildings.

Definite information was not available Sunday evening as to the extent of the torrential rains, but with the storm continuing it was evident that a near flood was in the offing. Therefore, a general warning was broadcast and messages dispatched to the river observers at Red Bluff and Hamilton City, including all others on the special warning list, that the Sacramento River would rise rapidly, reaching a stage of 22 feet Monday, April 8, at Red Bluff and 18 or 19 feet at Hamilton City Monday night. Early Monday morning flood warnings were issued for Knights Landing.

Excessive local rains over the Cottonwood and Battle Creeks areas on either side of Red Bluff caused the water to rise in that vicinity with great rapidity Sunday night, cresting Monday morning at Red Bluff with a stage of 23.6 feet, which was exceptionally high in proportion to the volume of water that came from upstream as indicated by the station of Kennett. In past years when a first order station was maintained at Red Bluff the official in charge there usually was able to supply some special information in regard to excessive local run-off from creeks in that vicinity. Oldtime residents on the east side of the valley south of Red Bluff reported that the run-off from local creeks was the greatest they had ever known.

It was just another instance of the erratic behavior of the streams of the Sacramento Valley, where even the output of a single creek with headwaters in the mountain area may cause a serious situation in the main stream, when excessive precipitation is localized.

The intensity of the flood crest that originated largely in the vicinity of Red Bluff was not sustained farther down the stream, due to the lack of proportionate run-off. The crest had flattened to 18.8 feet when Hamilton City was reached late Monday night. Crest stages occurred at Colusa and Knights Landing on Wednesday, April 10, the former at 25.1 feet, or 0.4 foot less than that forecast, and the latter at 30.2 feet, which was 0.3 foot below the stage expected.

The fact that the water slightly exceeded the flood stage for a few hours at Red Bluff without being forecast specifically as a flood was of no special importance, because the warnings that had been disseminated, in effect, covered the situation. This was true because the main interests to be served are in the lowlands farther down the stream where stages were not higher than expected. In reality no damage occurred in the immediate vicinity of Red Bluff.

Likewise, the American and Bear Rivers rose with great rapidity Sunday night, causing the Sacramento River at Sacramento to crest Monday evening at a stage of 28.6 feet, or 0.1 foot above that forecast, and 1 foot below the high-water mark established in March 1928, when the town of North Sacramento, situated across the American River from Sacramento, was completely flooded.

On Monday morning the water from the American River, which flows between the two cities, overspread an irregular area adjacent to the river. The few families living in this low area, outside the recently completed flood control levee that was constructed to protect North Sacramento, were driven from their homes and places of business, and highway traffic was interrupted when the floodgates to the passage through the levee on Del Paso Boulevard were closed Sunday night to keep out the oncoming water. By Thursday morning, April 11, the overflow water from the American River had receded sufficiently for the main highway between the two cities to be opened for traffic.

The levee that was constructed about the city of North Sacramento after the destructive flood of 1928 effectively protected that city during this high water.

The gates of the Sacramento Weir (constructed to protect the city of Sacramento from flood waters) were not opened; but at noon Monday the Courtland telephone operator was requested to distribute warnings to those in the lower Yolo basin area that water to a depth of about 1½ feet was flowing over the entire length of the 48 gates of the Sacramento Weir, and that Fremont Weir, already discharging freely, would intensify the danger in the lower bypass region within the next day or two.

The operation of the Sacramento Weir is under the control of the State Reclamation Board, and the gates may be opened when the situation warrants, which is usually well in advance of the occurrence of the flood stage, provided a critical situation is indicated. Therefore, the forecast of a definite stage in such emergencies is of vital importance, because to open the weir gates would result in wholesale destruction in the bypass area where substandard levees are the only protection to many thousands of acres of highly cultivated land, yet to defer the opening of the weir gates too long, especially if a heavy volume of water is yet to come, may endanger the populous area at Sacramento.

Unofficial reports that had gained wide circulation to the effect that another and more intense flood wave from the up-Sacramento River soon would be due unnecessarily alarmed the already highly frantic populace in and about Sacramento, and occasioned an additional deluge of inquiries to the Weather Bureau, where the single telephone service, from the beginning of the storm, was able to accommodate only a small percentage of the thousands who tried to call. One official of another department stated that he was unable to receive more than a "busy" response from the Weather Bureau telephone number during a 2-hour effort. On Monday morning the United States Commissioner, who has an office adjoining that of the Weather Bureau, kindly lent us the use of his telephone for a few hours. The additional service permitted the official in charge to answer the many long-distance calls that were awaiting his attention.

Relieving the excess flood waters that accumulated in the section from Knights Landing to the mouth of the Feather, Fremont Weir discharging into Yolo bypass at the rate of about 67,000 second-feet during the peak flow on the 10th–11th, was the principal source of the water that menaced thousands of acres of the low bypass lands, much of which had already been planted to crops. The greatest monetary loss resulted from the breaking of the levee on Prospect Island, which was planted to asparagus and other truck crops. This island and Little Holland Tract, situated near the outlet of Yolo bypass, were completely inundated. No doubt the relief afforded by the breaking of the levee on Prospect Island, causing the water level to drop about 10 inches, was a factor in saving the nearby Liberty Island from a similar fate.

Aside from the lower Yolo basin area, damage to agricultural lands and growing crops was limited, and mostly confined to small areas adjacent to streams in a few localities. Much of the submerged areas in the valleys were pasture and alfalfa lands where little or no damage resulted, stockmen having moved their livestock to higher grounds when warnings were received. With river stages remaining high for about a month, the continuation of seepage damage to lowlands abutting the levees in the lower valley areas caused considerable concern to agricultural interests.

Torrential local rains in a few foothill sections caused considerable damage in the way of washouts to highways and railroads. Heavy damage was reported to have been done to hillside orchards in Placer County by erosion of topsoil. Minor damage to levees occurred locally on the lower reaches of streams. A break occurred in the north levee of the lower Bear River in the vicinity of Wheatland and a hundred or more acres of alfalfa and orchard land were flooded, but the resultant damage was light. Also little loss resulted from the flooding of considerable acreage along the lower Cosumnes River above its confluence with the Mokelumne, in the lower San Joaquin basin.

The fact that practically all the water of the upper Mokelumne River want into storage in Pardee Dam on that stream, prevented what otherwise would have been a rather serious flood situation on the lower Mokelumne. As it was, the Cosumnes alone caused a near flood at the river station of Bensons Ferry on the lower Mokelumne. On the morning of April 8, cautionary warnings were issued for the streams tributary to the lower San Joaquin River. The Feather and Yuba Rivers were only moderately high. Had they been proportionately high as compared with other streams, the Knights Landing area would have suffered a serious flood and much more destruction would have been caused in the lower Yolo Basin.

With a recurrence of heavy local rains in the American and Bear River areas on April 15, these streams, especially the American, carried considerable water, and with the Sacramento already high, 23.3 feet at 8 a. m. of that date, cautionary warnings were issued to the effect that the river at Sacramento would rise to 26 feet during the night and that a portion of the low area between the two cities would again be submerged, and at the same time advised that the flood-control gates on Del Paso Boulevard be closed.

On the following morning the river at Sacramento peaked at a stage of 26.1 feet. Limited areas of the lowlands adjacent to the north side of the American River were covered with water, but as normal activities in that low region had not been resumed little damage resulted. By the morning of April 18 receding waters permitted the gates of the highway to be opened for traffic.

Five lives were lost by drowning: One at Sacramento when a boat of a rescuing party capsized, three in the vicinity of Lincoln, Placer County, east of Auburn, when local creeks suddenly overflowed their banks, and one at Vina, Tehama County, where a rancher was thrown from his horse while rounding up cattle in the flooded area.

The damage to property as a result of this flood was estimated at $526,150; and the value of the property saved by the Weather Bureau's warnings was estimated to be $318,000.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, *in charge of Library*

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Abercromby, Ralph
Weather; the nature of weather changes from day to day. New ed., rev. and largely rewritten, by A. H. R. Goldie. London, K. Paul, Trench, Trubner & co., ltd. 1934. xii, 274 p. illus. (incl. charts), plates, double chart, diagrs. 22 cm. (Bibliography at the end of all but two chapters.)

Blue Hill Observatory fifty years old. n. p. n. d. 11 p. illus. 25 cm. (Reprinted from The Harvard alumni bulletin.)

Carvalho Andrêa, Á.
Meteorologia e medicina. Lisboa. 1934. 16 p. 25 cm. (Separata de Medicina, revista de ciências mêdicas e humanismo. Lisboa. Julho 1934.)

Fàntoli, Amilcare
L'ambiente agro-meteorologico del Fezzán. Roma. 1930—Anno IX. 13 p. 24 cm. (Estratto dalla Rassegna Economica delle Colonie, maggio-giugno 1930—VIII—nn. 5–6.)
——— L'ambiente fisico delle Colonie Libiche nei suoi riflessi demografici e nelle sue influenze sul lavoro indigeno. Roma. 1932—Anno X. 19 p. fold. plate, diagrs. 24 cm.
——— L'organizzazione meteorologica in Libia. Roma. 1929—Anno VII. 8 p. 24 cm. (Estratto dalla Rassegna Economica delle Colonie. Fascicolo 3–4—1929—VII.)
——— Se esista una relazione fra il ciclo undicennale dell' attività solare e le pioggie in Libia. Tripolitania. 1934—XII. 18 p. fold. pls. tables. 21½ cm. (Estratto dal Bollettino Geografico N. 4 dell' Ufficio Studi del Governo della Tripolitania.)
——— Gli studi agro-meteorologici in Libia. Roma. 1932—Anno X. 16 p. 24 cm. (Estratto dalla Rassegna Economica delle Colonie. Luglio-Agosto 1931—IX—n. 7–8.)
——— La zona degli altipiani nord-orientali della Tripolitania. Sguardo climatologico. n. p. n. d. 18 p. fold. plate, tables. 23 cm.